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MEMORANDUM

May 24, 2007

To: Secretary Ian Bowles and Staff, MA EOEEA
Cc: Dan Sosland, Roger Koontz, and Sam Krasnow, ENE
Rob Pratt, Doug Foy, & David Dayton, Kendall Foundation
Michelle Manion, NESCAUM
From: Derek Murrow, Director - Policy Analysis, ENE

RE: **Estimates of the Benefits of Expanded CHP and Solar Capacity in MA**

This document is an attempt to identify some order of magnitude energy and emissions benefits associated with adding new combined heat and power (CHP) and solar capacity to the electricity system in Massachusetts. These are rough estimates calculated by Environment Northeast (ENE) based on the impact of adding demand-side generation to the New England power pool that reduces demand for system power and therefore depresses the wholesale electric price.

We examined the following CHP and solar capacity additions to estimate potential reductions in wholesale electric costs for all consumers/ratepayers.

- **250-CHP**:
    - At an 80% capacity factor, 250 MW of CHP could save approximately \$66 million over 1 year and a net present value (NPV) of approximately \$465 million over 10 years (7% discount rate for all), and approximately 0.7 million tons of CO_2 annually.
    - At a 60% capacity factor 250 MW of CHP could save approximately \$50 million over 1 year and a NPV of approximately \$349 million over 10 years, and approximately 0.5 million tons of CO_2 annually.
    - The range of NPV savings for all Massachusetts ratepayers over ten years, with capacity factors of 60-80%, is approximately \$349-465 Million.

- **500-CHP**:
    - At an 80% capacity factor, 500 MW of CHP could save approximately \$133 million over 1 year and a NPV of approximately \$931 million over 10 years, and approximately 1.4 million tons of CO_2 annually.
    - At a 60% capacity factor 500 MW of CHP could save approximately \$99 million over 1 year and a NPV of approximately \$698 million over 10 years, and approximately 1.0 million tons of CO_2 annually.
    - The range of NPV savings for all Massachusetts ratepayers over ten years, with capacity factors of 60-80%, is approximately \$698-931 Million.

The reduced energy costs do not include on-site savings for a CHP host that might see its energy costs go down. They also do not address potential energy savings to all consumers from reduced air conditioner load (some CHP can use thermal output for both heating and cooling).

- **10-Solar**: 10 MW of Photovoltaic could save approximately $1.5 million over 1 year and a NPV of approximately $10 million over 10 years, and approximately 12 thousand tons of CO_2 annually.

- **25-Solar**: 25 MW of Photovoltaic could save approximately $2.9 million over 1 year and a NPV of approximately $21 million over 10 years, and approximately 24 thousand tons of CO_2 annually.

These benefits must be weighed against the cost of any policy or incentive being developed by the state. As discussed below, creating incentives for a portion of the capacity cost of CHP facilities may be compensated for by the energy savings to all consumers, but the costs and benefits should be carefully weighed for a mature technology like CHP. At this time we do not believe significant incentives will be necessary for CHP as long as existing barriers are removed. In the case of solar which is really still in the commercialization phase, policy incentives may need to be created to help drive down the price, knowing that the cost will outweigh the benefits in the near term.

Estimating Wholesale Electric Market Benefits

The cost of wholesale electricity is soon to have two primary costs: (1) capacity, or payments to ensure there is generating capacity to meet peak demand, and (2) energy, or the cost of delivered energy on a given hour which is driven by the operating (fuel) and maintenance costs of the plants on the margin.

The cost of energy is driven by the operation and maintenance (O&M) costs of power plants, with the largest cost being fuel. The idea behind the competitive generation market in New England is that plants will either enter into bilateral energy contracts with load serving entities or they will bid into the day ahead or real-time markets and the ISO selects generating assets to dispatch based on their bid price.

ISO's *2005 Annual Markets Report* from June of 2006 (Figure 1, below) presents a simulated supply curve for peak days in 2004 and 2005. This gives a sense of the benefits of adding lower-cost peaking generation during periods of high demand. As fossil fuel prices change, the supply curve will change. However, with natural gas and oil primarily on the margin, we are assuming that the slope of the supply curve will remain relatively constant at the high end but shift up and down (appears to be the trend between 2004 and 2005). Figure 2 illustrates the relationship between natural gas prices and wholesale electric prices.

Figure 1: ISO New England Supply Curve (Peak Day)

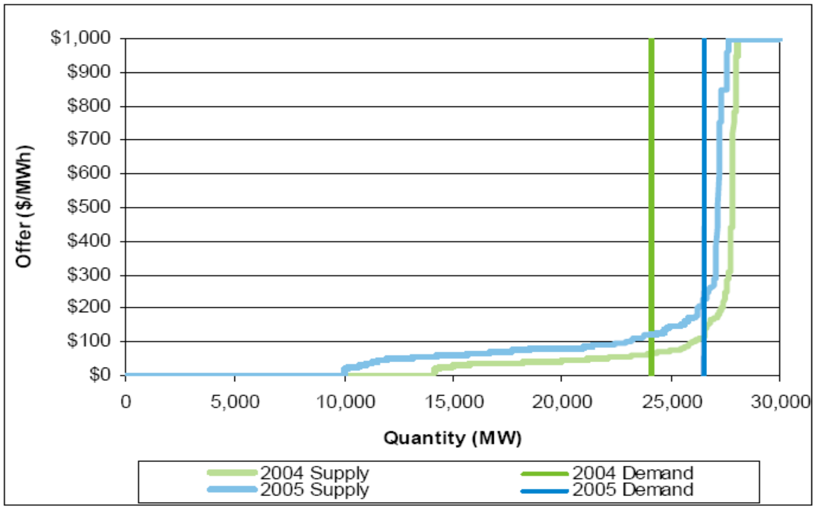


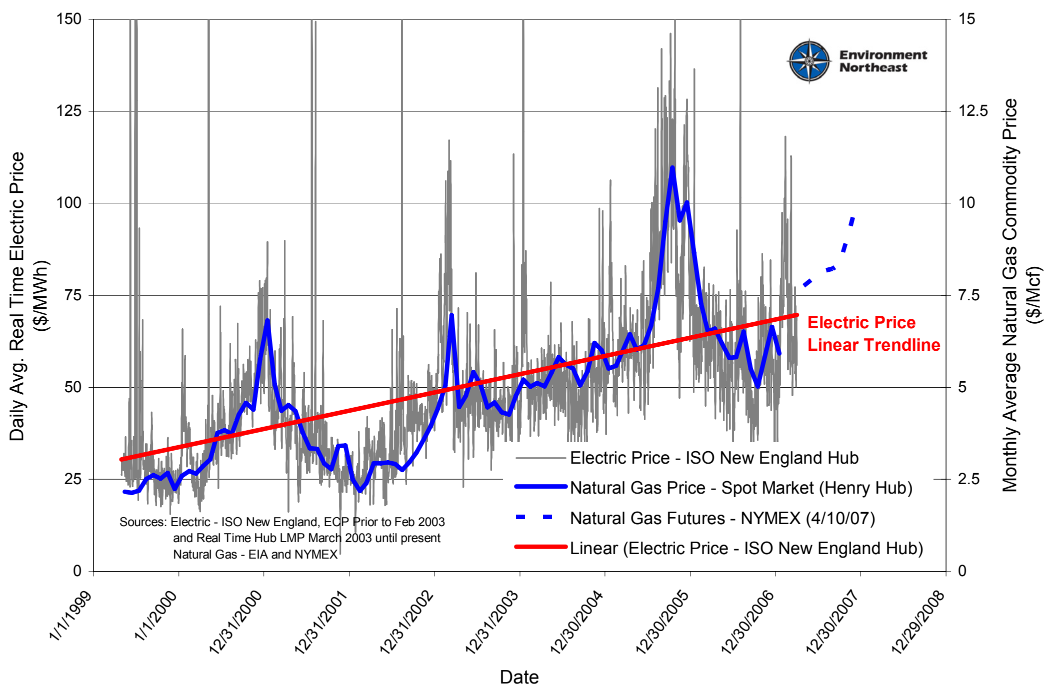
Figure 1-2: Simulated supply and demand balance and resulting impact on price, peak day, 2004 and 2005.

Source: ISO New England, June 2006, *2005 Annual Markets Report* , Page 3

ENE Estimate of the Slope of the 2005 Supply Curve

Demand	Change in Offer ($/MWh)	Change in Demand (MW)	Slope or Change in Price for Every MW Change
12,000 - 22,500 MW	$50	10,500	$0.005
22.500 - 27,000 MW	$100	4,500	$0.022

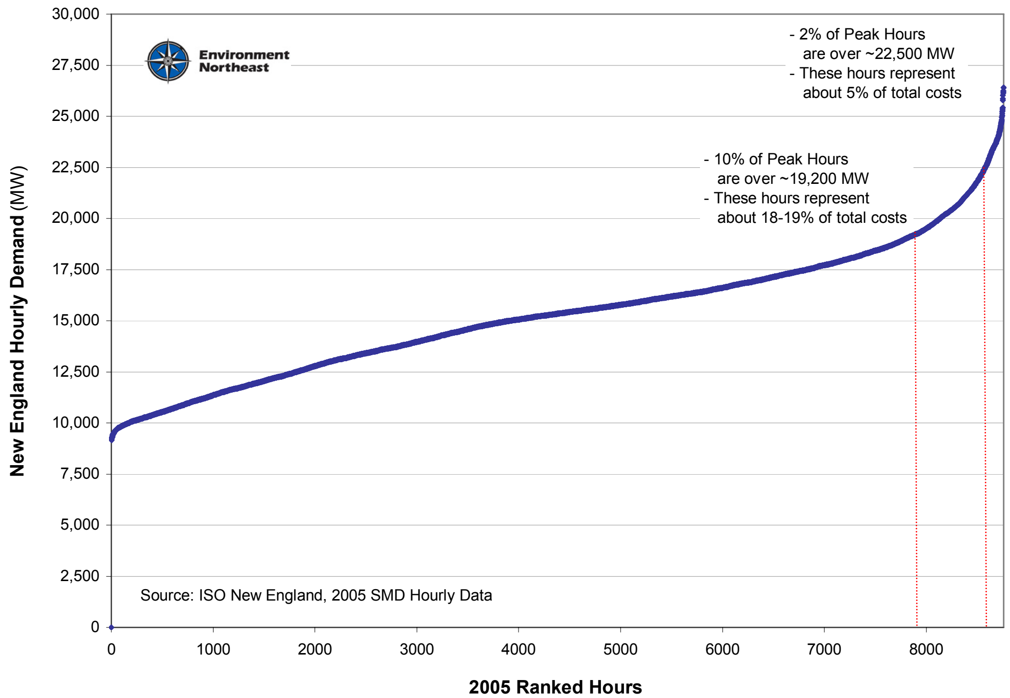
Figure 2: Wholesale Electric Energy Prices vs. Natural Gas Prices



ISO has not published similar supply curves and cost curves by control area or node. ENE used the 2005 supply curve in Figure 1 to estimate the slope of the supply curve during peak and off-peak hours. As shown at the bottom of Figure 1, we calculated the slope of the curve to be ~0.005 $/MW for New England demand between ~12,000 and 22,500 MW and ~0.022 $/MW between 22,500 and 27,000 MW.

As shown in Figure 3, below, the number of hours in 2005 that exceeded 22,500 MW was ~2%.

Figure 3: New England Peak Electricity Demand in 2005



For both CHP and solar additions, we assumed that the additional capacity primarily serves on-site loads and is not bid into the market. This has the effect of adding very low cost capacity or reducing demand and shifting demand down the supply curve by the number of MW of additional supply added to the system.

Note that if the CHP or solar units were grid connected and bidding most of their power into the ISO New England market this analysis would not be accurate.

This analysis does not address capacity costs and savings, as we assume the units would be paid through the capacity market and would not have a significant impact on that market.

Combined Heat and Power Benefits

The following are the estimated benefits of adding CHP to the system in terms of energy savings for all customers and emissions reductions. For the CHP analysis, we have looked at a range of capacity factors of 60 and 80% but believe that most projects should and could exceed 65%.

- **250-CHP**:
  - 250 MW of CHP, 80% capacity factor, equal distribution of generating hours among peak and off-peak periods
    - Wholesale electric price reduction in hours >22,500 MW of approximately $5.5/MWh
    - Wholesale electric price reduction in hours <22,500 MW of approximately $1.3/MWh
    - 1 year cost reduction for MA in peak 2% of hours of approximately $7.0 million
    - 1 year cost reduction for MA for remaining hours of approximately $59 million
    - Total 1 year cost reduction of approximately $66 million
    - Net present value of 10 years of savings at a 7% discount rate of approximately $465 million
  - 250 MW of CHP, 60% capacity factor, equal distribution of generating hours among peak and off-peak periods
    - Wholesale electric price reduction in hours >22,500 MW of approximately $5.5/MWh
    - Wholesale electric price reduction in hours <22,500 MW of approximately $1.3/MWh
    - 1 year cost reduction for MA in peak 2% of hours of approximately $5,.3 million
    - 1 year cost reduction for MA for remaining hours of approximately $44 million
    - Total 1 year cost reduction of approximately $50 million
    - Net present value of 10 years of savings at a 7% discount rate of approximately $349 million

- **500-CHP**:
  - 500 MW of CHP, 80% capacity factor, equal distribution of generating hours among peak and off-peak periods
    - Wholesale electric price reduction in hours >22,500 MW of approximately $11/MWh
    - Wholesale electric price reduction in hours <22,500 MW of approximately $2.5/MWh
    - 1 year cost reduction for MA in peak 2% of hours of approximately $14 million
    - 1 year cost reduction for MA for remaining hours of approximately $118 million
    - Total 1 year cost reduction of approximately $133 million
    - Net present value of 10 years of savings at a 7% discount rate of approximately $931 million
  - 500 MW of CHP, 60% capacity factor, equal distribution of generating hours among peak and off-peak periods
    - Wholesale electric price reduction in hours >22,500 MW of approximately $11/MWh
    - Wholesale electric price reduction in hours <22,500 MW of approximately $2.5/MWh
    - 1 year cost reduction for MA in peak 2% of hours of approximately $11 million
    - 1 year cost reduction for MA for remaining hours of approximately $89 million
    - Total 1 year cost reduction of approximately $99 million

- Net present value of 10 years of savings at a 7% discount rate of approximately $698 million

In order to estimate the emissions benefits of adding CHP to the system, we have used EPA's CHP Emissions Calculator (http://www.epa.gov/CHP/project_resources/calculator.htm). The following are summary benefits associated with adding 250 MWs of CHP to the system assuming two different technologies a 1 MW engine and a 10 MW combustion turbine. These results are heavily influenced by the assumptions in terms of the system being replaced and the heating and cooling equipment loads and characteristics. The actual systems installed would likely vary widely, but the order of magnitude benefits are likely good estimates.

Table 1: Estimates of CHP Emissions Benefits

	1 MW Lean-Burn Engine				10 MW Combustion Turbine				250 MW Totals	
	CHP System	Displaced System	Reduction	% Reduction	CHP System	Displaced System	Reduction	% Reduction	1 MW Lean-Burn Engine	10 MW Combustion Turbine
NOx (Tons/year)	7	10	3	27%	41	106	65	61%	664	1,616
SO2 (Tons/year)	0	25	25	100%	0	267	266	100%	6,274	6,661
CO2 (Tons/year)	4,062	6,971	2,909	42%	48,247	74,558	26,311	35%	727,127	657,784
Fuel (MMBtu/year)	69,442	89,291	19,850	22%	824,733	954,805	130,073	14%	4,962,471	3,251,815

Assumptions (See EPA CHP Emissions Calculator results for full details):
Note: these assumptions are relatively optimistic in terms of operation and the systems being replaced

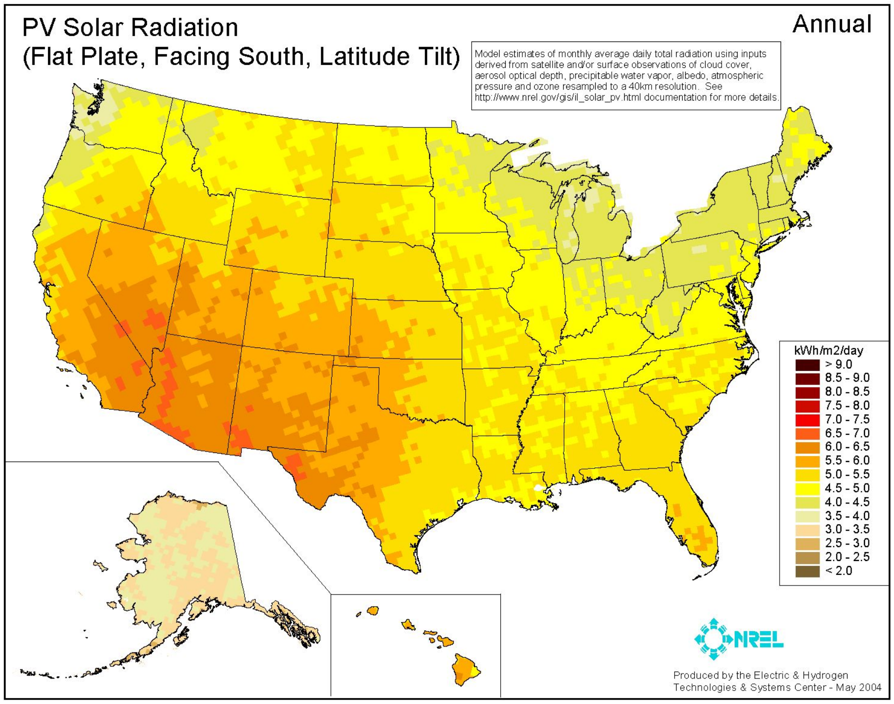
Unit Size:	1.0 MW	10.0 MW
Capacity Factor:	80%	80%
Electric Effic:	34%	29%
Fuel:	Natural gas	Natural gas
Emissions Rates:	EPA defaults	EPA defaults
Heating/Cooling:	50/50	50/50
New Chiller:	Single effect adsorption chiller	Single effect adsorption chiller
Chiller Replaced:	1980s vintage rooftop unit	1980s vintage rooftop unit
Boiler Replaced:	Distillate oil boiler	Distillate oil boiler
Sulfur Content:	High sulfur oil - 1,500 ppm	High sulfur oil - 1,500 ppm
Displaced Electric:	EPA defaults for MA (average rate)	EPA defaults for MA (average rate)

As indicated in Table 1, adding 250 MW of CHP could yield CO_2 benefits in the range of 0.7 million tons of CO_2 per year. This is an approximately 35-42% reduction in emissions for the facilities that install CHP and is equivalent to slightly less than 1% of MA total annual CO_2 emissions due to fossil fuel combustion. If the capacity factor is reduced to 60%, the emissions benefits are closer to 0.5 million tons of CO_2 per year.

Solar Photovoltaic Benefits

The following are the estimated benefits of adding Solar Photovoltaic to the system in terms of energy savings for all customers and emissions reductions. The solar resource in the Northeastern US is relatively limited which reduces the capacity factor of any photovoltaic panels (PV) installed. The figure below shows the relative solar radiation in different parts of the United States.

Figure 4: Average Solar Radiation in the United States



We have assumed a capacity factor of 10% for solar PV installed in MA, which may be on the optimistic side. However, peak power days tend to coincide with hot summer days when PV panels usually generate at full capacity. For this reason we have assumed that PV is operational during 100% of peak hours in a year (top 2% or hours over 22,500 MW).

- **25-Solar**: 25 MW of Photovoltaic, 10% capacity factor, 100% solar coincidence with the top 2% of demand hours in a year, other hours assumed to be average
  - Wholesale electric price reduction in hours >22,500 MW of approximately $0.55/MWh
  - Wholesale electric price reduction in hours <22,500 MW of approximately $0.13/MWh
  - 1 year cost reduction for MA in peak 2% of hours of approximately $0.9 million
  - 1 year cost reduction for MA for remaining hours of approximately $0.6 million
  - Total 1 year cost reduction of approximately $1.5 million
  - Net present value of 10 years of savings at a 7% discount rate of approximately $10 million

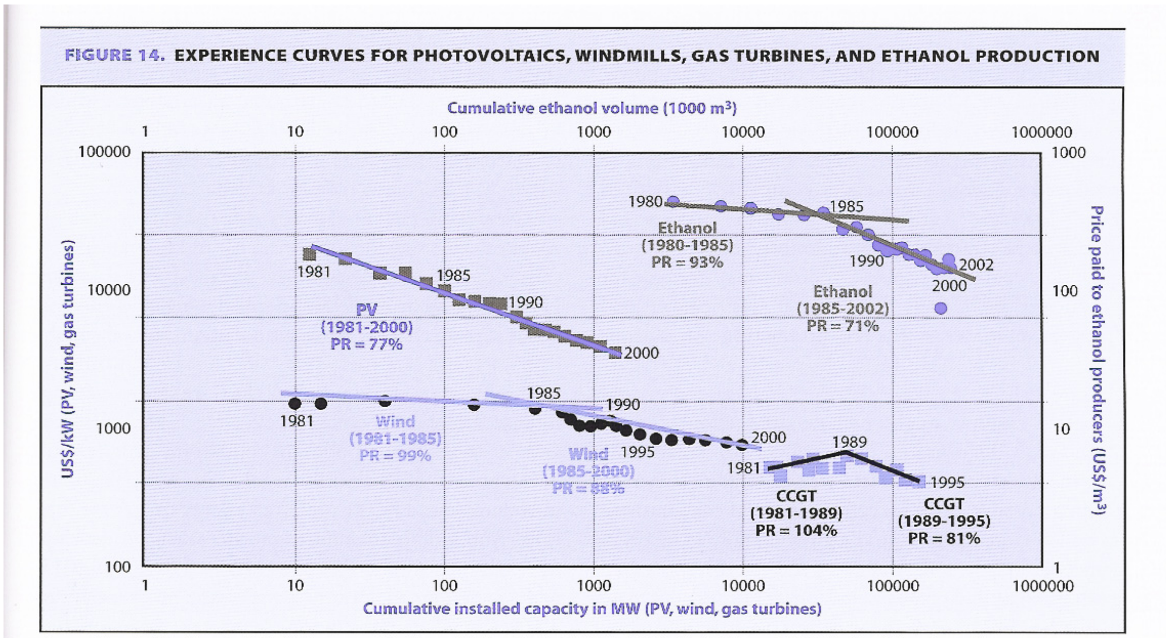
- **50-Solar**: 50 MW of Photovoltaic, 10% capacity factor, 100% solar coincidence with the top 2% of demand hours in a year, other hours assumed to be average
  - Wholesale electric price reduction in hours >22,500 MW of approximately $0.11/MWh
  - Wholesale electric price reduction in hours <22,500 MW of approximately $0.25/MWh
  - 1 year cost reduction for MA in peak 2% of hours of approximately $1.8 million
  - 1 year cost reduction for MA for remaining hours of approximately $1.2 million
  - Total 1 year cost reduction of approximately $2.9 million
  - Net present value of 10 years of savings at a 7% discount rate of approximately $21 million

Although an unlikely quantity of PV in the near term, we did look at 250 MW of PV for comparison to CHP and the benefits over 1 year are approximately $15 million with a NPV over 10 years of $103 million.

The capacity cost of new solar is quite high, but it is zero emitting and has almost no operating costs (no fuel costs). It is one of those technologies that needs more commercialization support in order to drive down prices. All-in energy costs for are currently in the 40-60 cents/kWh range (see Solarbuzz survey of current prices and costs: http://www.solarbuzz.com/SolarIndices.htm).

The learning curve for solar PV is very impressive with costs declining quite rapidly in relation to the quantity produced (see Figure 5, below). Solar PV definitely deserves commercialization support as one of the key technologies that will assist the region and the world achieve energy and climate goals.

Figure 5: Experience Curves for PV and Other Technologies (*World Energy Assessment, 2004 Update*)



Sources: For wind turbines, L. Neij., P. Dannemand Andersen., M. Durstewitz, P. Helby, M. Hoppe-Kilpper, and P.E. Morthorst, Experience Curves: A Tool for Energy Policy Assessment *(March 2003); for gas turbines, U. Claeson Colpier and D. Cornland, "The Economics of the Combined Cycle Gas Turbine: An Experience Curve Analysis",* Energy Policy *30, no. 4 (2002), pp 209–216; for photovoltaics, V. Parente, R. Zilles, and J. Goldemberg, "Comments on Experience Curves for PV Modules",* Progress in Photovoltaics: Research and Applications, *John Wiley & Sons, Ltd (2002); for ethanol, J. Goldemberg, S.T. Coelho, P. M. Nastari, and O. Lucon, "Ethanol Learning Curve: The Brazilian Experience",* Biomass and Energy *(in publication).*

The emissions benefits of solar PV are relatively straightforward to estimate. It is a zero emitting resource, so for every unit of energy generated there should be a reduction in demand for marginal power in the region. The following are the emissions benefits for 25 and 50 MW of solar PV based on ISO New England marginal emissions rates (ISO New England, May 2006, *2004 New England Marginal Emission Rate Analysis*) and the 10% capacity factor assumed above.

25-Solar: 22 tons of SO_2, 6 tons of NO_x, and 12 thousand tons of CO_2
50-Solar: 44 tons of SO_2, 12 tons of NO_x, and 24 thousand tons of CO_2